US005290121A

United States Patent [19]

Dolce et al.

[11] Patent Number: 5,290,121

[45] Date of Patent: Mar. 1, 1994

[54] **SYSTEM FOR THE INSTALLATION AND REPLACEMENT OF COMPONENTS IN HOSTILE ENVIRONMENTS**

[75] Inventors: **James L. Dolce**, Lakewood; **Andrew L. Gordan**, Cleveland, both of Ohio

[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**, Washington, D.C.

[21] Appl. No.: **889,572**

[22] Filed: **May 28, 1992**

[51] **Int. Cl.**[5] **B25B 5/00**; B25B 5/10; F16H 27/06

[52] **U.S. Cl.** **403/322**; 24/513; 74/89.15; 74/436; 269/94; 269/238; 269/242; 269/309; 403/373

[58] **Field of Search** 74/436, 89.15; 24/504, 24/513; 269/94, 238, 242, 309; 403/322, 353, 373, 374

[56] **References Cited**

U.S. PATENT DOCUMENTS

970,888	9/1910	Conboy	269/242 X
1,027,695	5/1912	Covert	269/94 X
2,242,487	5/1941	Swanson	269/242 X
2,660,926	12/1953	Talley	74/436 X
2,788,929	4/1957	Gallagher	269/242 X
2,997,682	8/1961	Grimes et al. .	
3,170,214	2/1965	Cochrane	269/94 X
3,361,005	1/1968	Carpenter	74/436
4,115,020	9/1978	Langsford .	
4,821,393	4/1989	Spigarelli	269/242 X
4,959,609	9/1990	Prokopp et al. .	
4,990,022	2/1991	Watanabe et al. .	

FOREIGN PATENT DOCUMENTS

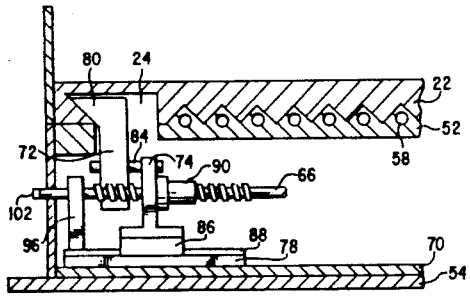
571327	8/1945	United Kingdom	269/238

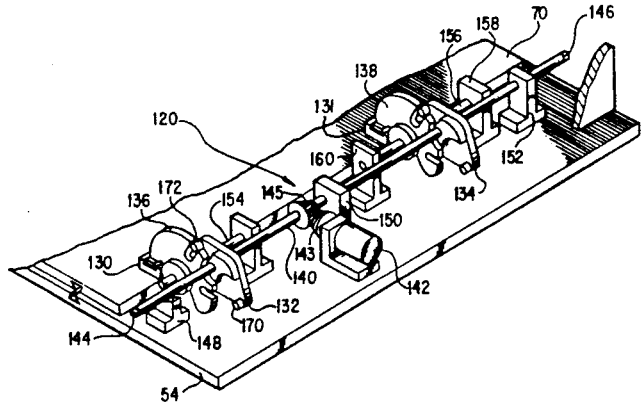
Primary Examiner—Allan D. Herrmann
Attorney, Agent, or Firm—Gene E. Shook; Guy M. Miller; James A. Mackin

[57] **ABSTRACT**

Service equipment for use in hostile environments includes a detachable service unit secured to a stationary service unit. The detachable service unit includes a housing with an exterior plate, a power control interface for connection to an exterior power source, locating pins located in said exterior plate, an electrical connector in the exterior plate electrically coupled to said power control interface, and a pair of clamping receptacles formed in the exterior plate and located on adjacent opposite edges of the exterior plate. The stationary unit includes an electrical connector for connection to the electrical connector of the detachable service unit, a clamping apparatus for clamping and unclamping the detachable service unit from the stationary unit, a base clamp assembly for mounting the clamping apparatus onto the stationary unit, and locating pin holes for receiving the locating pins and aligning the detachable service unit onto the stationary unit. The detachable service unit and stationary unit have mating scalloped faces which aid in alignment and provide a mechanism for heat dissipation.

16 Claims, 4 Drawing Sheets





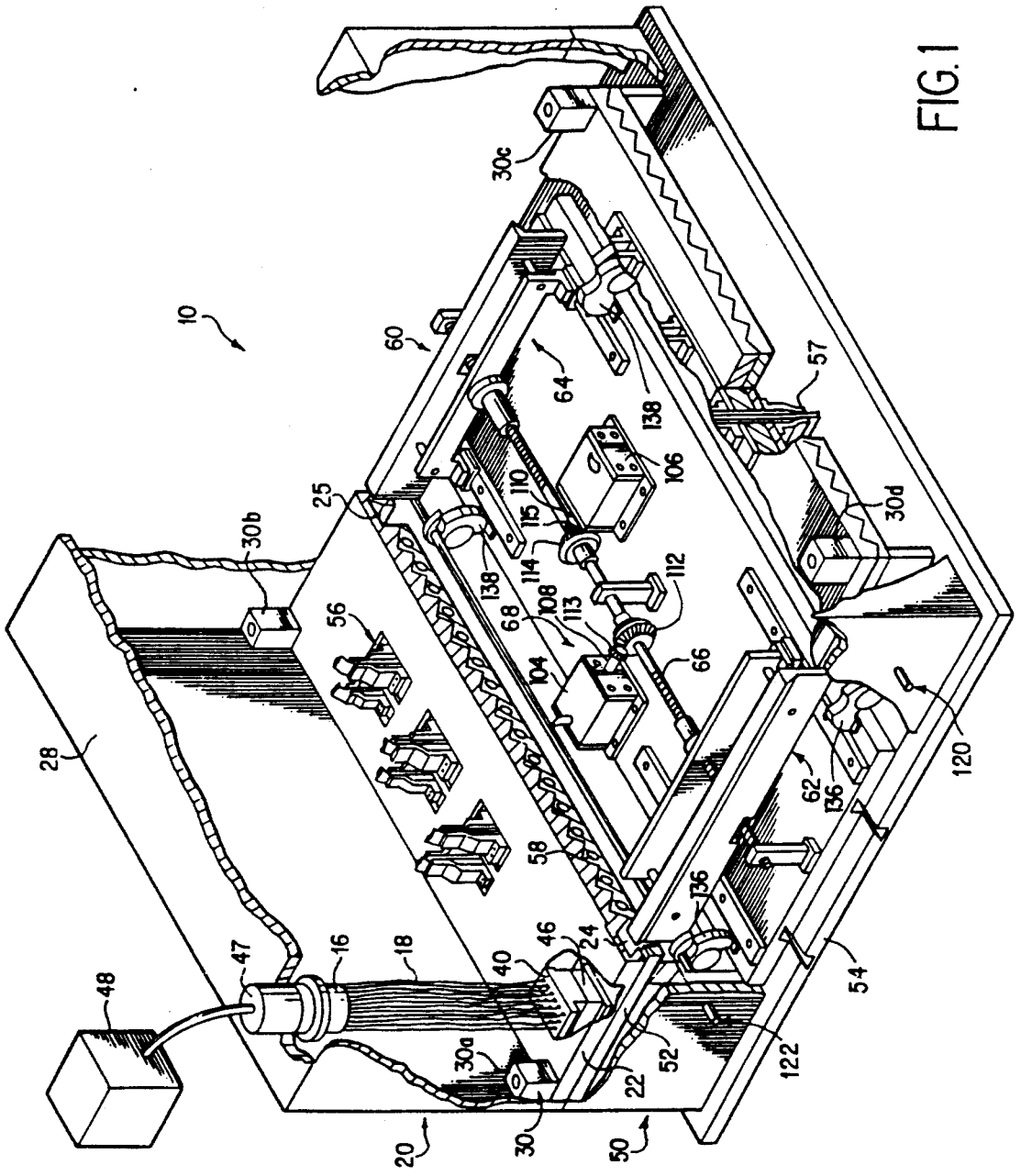

10
60
64
138
106
57
30c
25
30b
30d
110
115
114
112
108
113
68
104
66
56
28
58
62
136
120
54
122
52
22
46
24
40
18
16
47
48
30a
30
20
50

FIG. 1

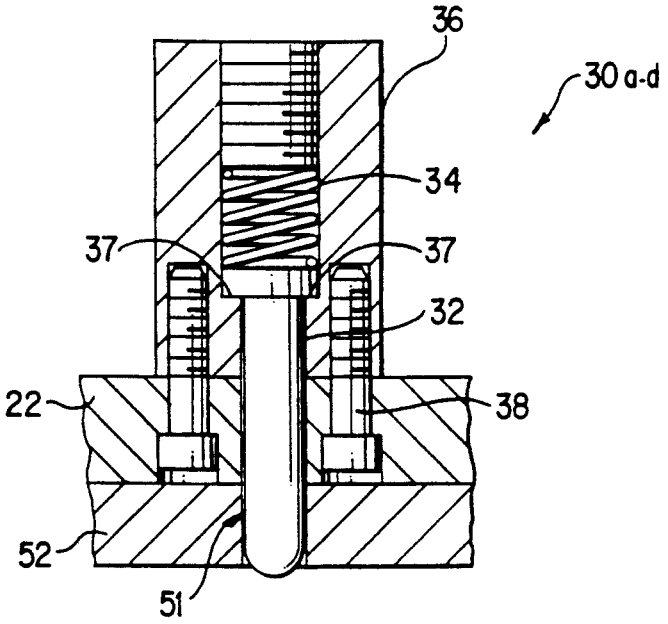


FIG. 2

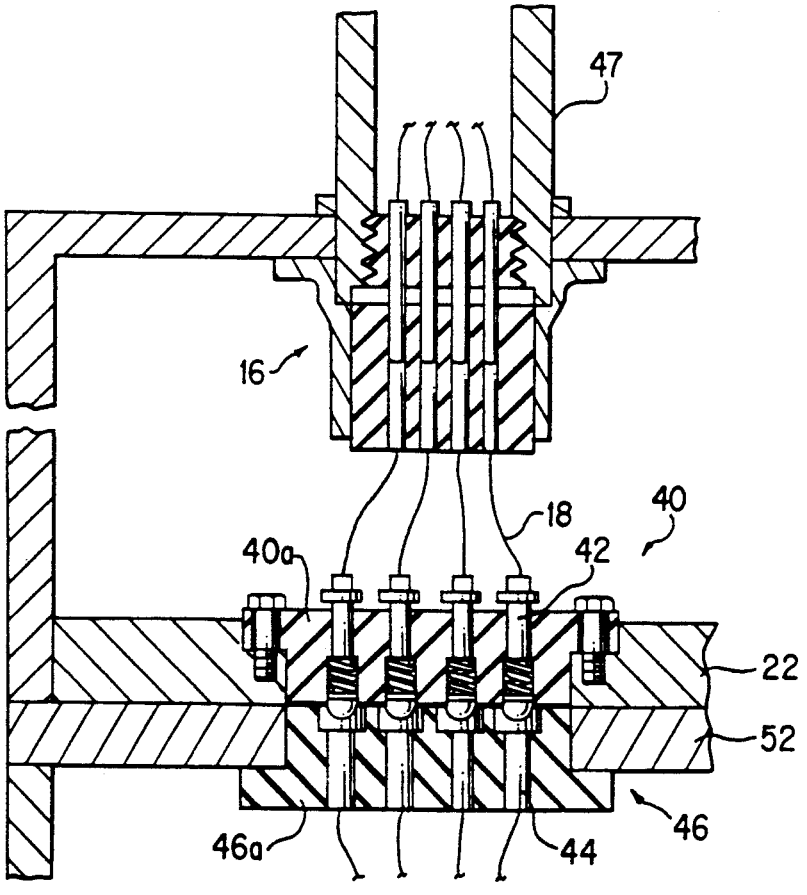


FIG. 3

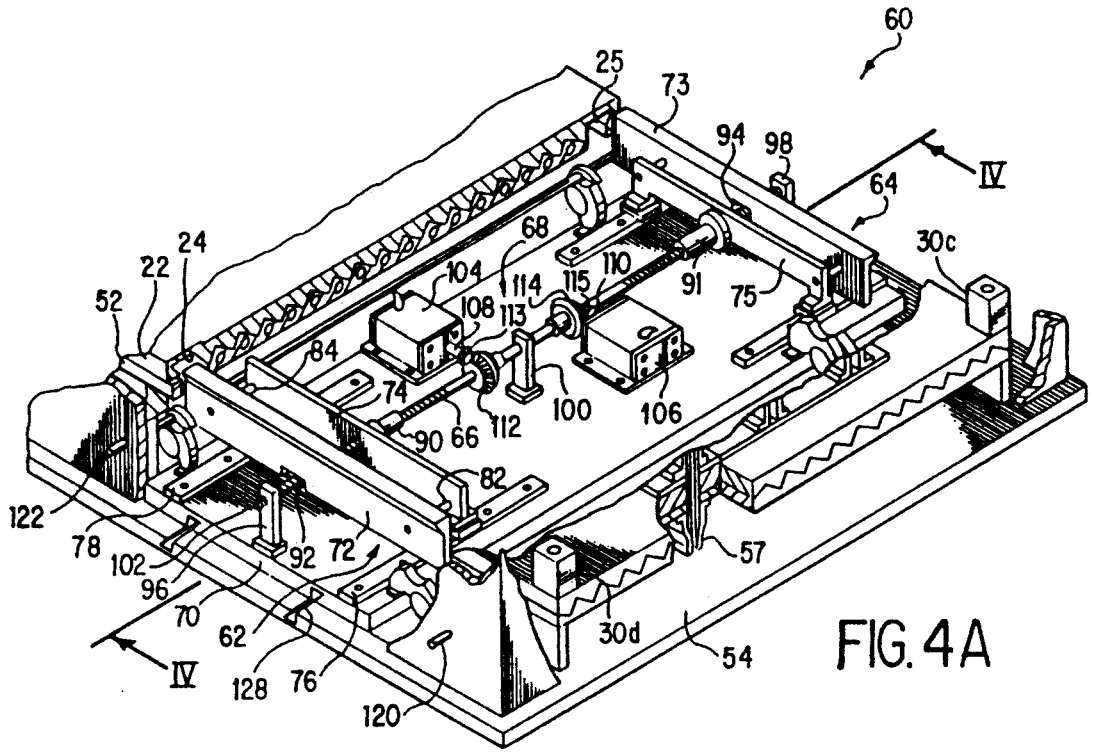


FIG. 4A

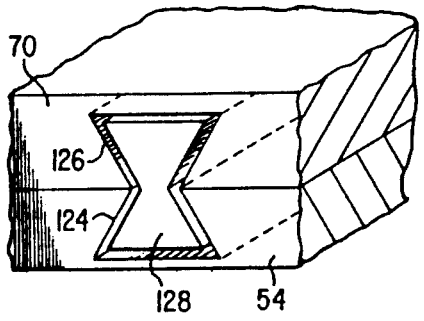


FIG. 4C

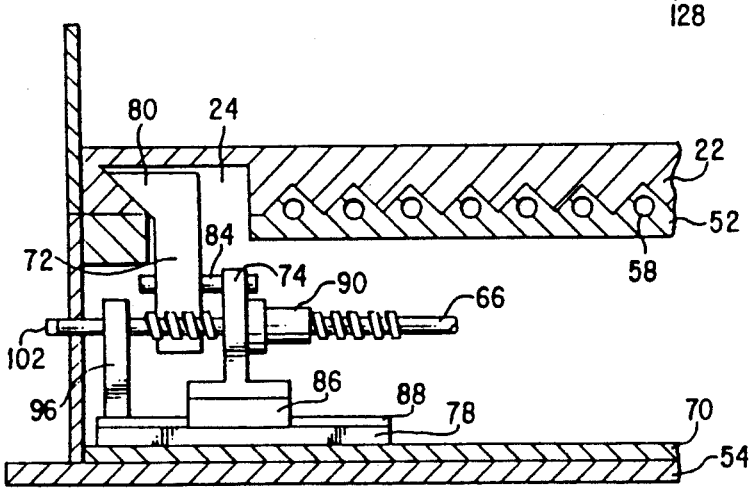


FIG. 4B

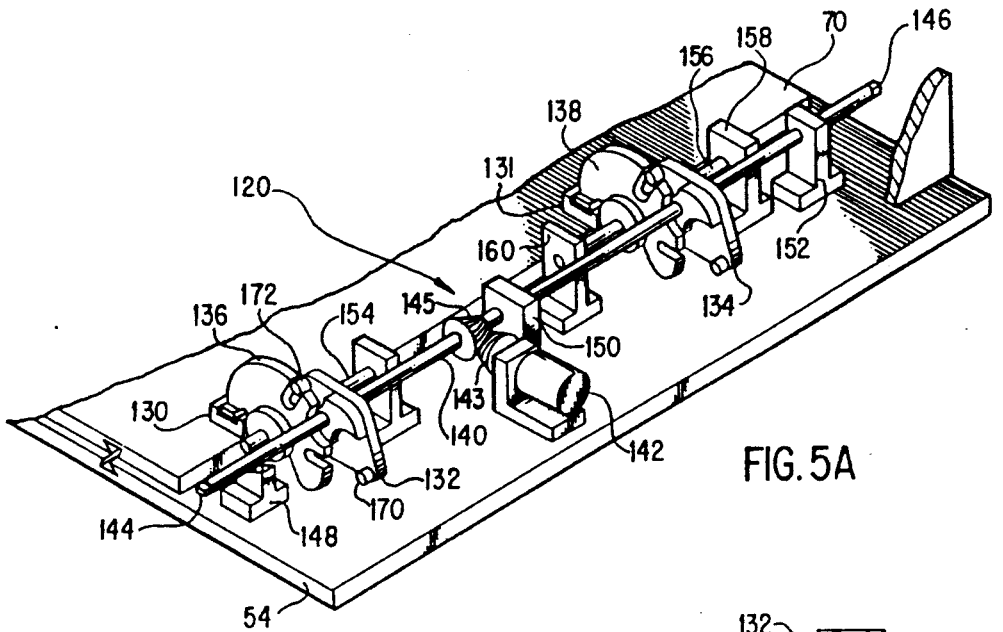


FIG. 5A

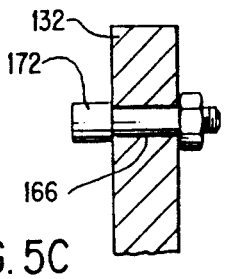


FIG. 5C

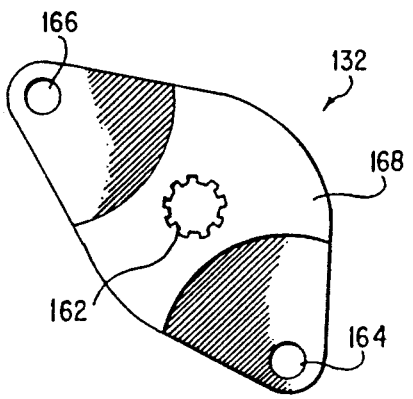


FIG. 5B

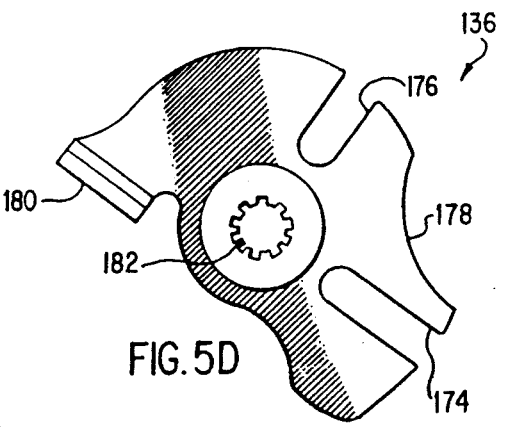


FIG. 5D

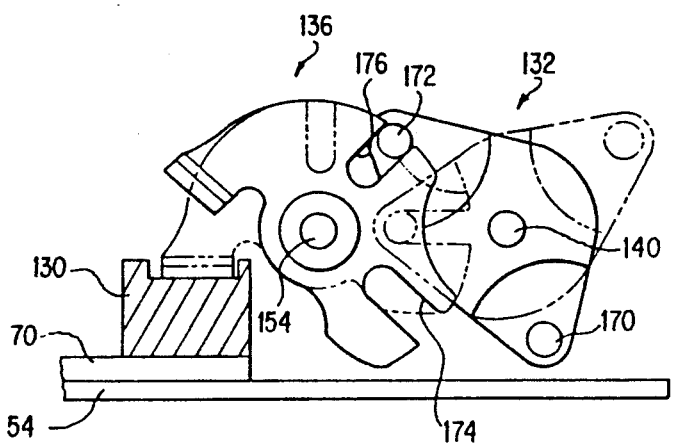


FIG. 5E

SYSTEM FOR THE INSTALLATION AND REPLACEMENT OF COMPONENTS IN HOSTILE ENVIRONMENTS

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government, together with a contractor employee performing work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Statute 435; 42 U.S.C. 2457).

FIELD OF THE INVENTION

The present invention is directed to installation, maintenance or replacement of service equipment in hostile environments, e.g., space, nuclear facilities, etc., and in particular to installation, maintenance or replacement of electrical, electronic and mechanical service equipment by a person with a power pac, by robotic end effectors controlled through a remote computer terminal interface or by a person controlling the robotic end effectors.

BACKGROUND

In hostile environments, such as in space and nuclear facilities, access to service equipment components is limited and direct human control of the components is usually prohibited. Further, the components may experience unforeseen problems, due to the particular environment, which require on site correction. For example, a NASA space station has many components which are directly exposed to the harsh environment of space. Astronauts on the space station cannot easily access such components for maintenance and replacement in the event that the service equipment becomes inoperative. Thus, there is a need to provide an effective method for installing, maintaining and replacing service equipment, such as a service unit which can be easily and quickly clamped and unclamped from the service equipment for service or replacement.

Conventional clamping assemblies are generally unsuitable for use in hostile environments, since conventional clamps are usually designed for direct access. For example, U.S. Pat. No. 4,115,020 to Langsford discloses a clamp for attaching clip-on units to a cargo container wherein the clamp is formed as a pivotal arm receivable in an opening for locking. Such a clamp is unsuitable for space station use because the clamp is not designed for remote access.

Further, service equipment generally includes electrical connectors for controlling various electrical and mechanical devices in the hostile environment. Electrical connectors are needed which can be easily and accurately connected and disconnected in order to cooperate with the clamping and unclamping of the service equipment. Conventional electrical connectors presently used by the military or commercial industry require precise alignment and are therefore unsuitable for use in combination with limited access clamping assemblies used in hostile environments. U.S. Pat. No. 2,997,682 to Grimes et al., U.S. Pat. No. 4,959,609 to Prokopp et al. and U.S. Pat. No. 4,990,022 to Watanabe et al. disclose examples of such conventional electrical connectors.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the present invention to provide a system in which service equipment can be easily and quickly installed, maintained and replaced in a hostile environment.

It is another object of the present invention to provide a clamping apparatus which can be controlled automatically or manually for installation, maintenance and replacement of service equipment in a hostile environment.

It is another object of the present invention to provide a clamping apparatus which can be removed and replaced while in the hostile environment.

It is a further object of the present invention to provide service equipment having an efficient thermal interface for temperature control of service equipment in a hostile environment.

To achieve the foregoing and other objects and advantages, and to overcome the shortcomings of conventional devices discussed above, service equipment for use in hostile environments in accordance with the present invention comprises a detachable service unit including an exterior plate, a power control interface for connection to an exterior power source, at least two locating pins located on the exterior plate, a first electrical connector coupled to the exterior plate and electrically coupled to the power control interface, and a pair of clamping receptacles formed on adjacent opposite edges of the lower surface of the exterior plate; and a stationary unit including a second electrical connector for connection to the first electrical connector, a clamping apparatus for clamping and unclamping the detachable service unit from the stationary unit, a clamp assembly for mounting the clamping apparatus onto the stationary unit, and at least two locating pin holes for receiving the locating pins of the detachable service unit and aligning the detachable service unit onto the stationary unit.

Furthermore, the clamping apparatus in accordance with the present invention, for manual or robotic replacement of a detachable service unit from a stationary unit in hostile environments, comprises a clamping base plate for mounting to the stationary unit, a pair of opposing clamp units coupled to the clamping base plate, and a drive assembly secured to the pair of opposing clamp units, including a drive shaft and at least one drive mechanism for rotating the drive shaft to cause linear displacement of the pair of opposing clamp units and thus move the pair of opposing clamp units between a clamped position and an unclamped position to clamp and unclamp the detachable service unit from the stationary unit.

Also, the clamp assembly in accordance with the present invention, for removable securement of units in a modular assembly, comprises a Geneva cam driver having a spline, an engagement roller, a disengagement roller and an interlocking formation; an irregular Geneva cam having an engagement groove for receiving the engagement roller of the Geneva cam driver, a disengagement groove for receiving the disengagement roller of the Geneva cam driver, an arc groove and a clamp face; a drive shaft coupled to the spline of the Geneva cam driver; and an operating mechanism for rotating the drive shaft in a first direction to cause the engagement roller to engage the engagement groove and to cause the clamp face to clamp a unit to the modu-

lar assembly, and for rotating the drive shaft in a second direction to cause the disengagement roller to engage the disengagement groove and to cause the clamp face to unclamp the unit from the modular assembly.

Other objects, advantages and salient features of the invention will become apparent from the following detailed description which, taken in conjunction with the annexed drawings, discloses preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in detail with reference to the following drawings, in which like reference numerals refer to like elements, wherein:

FIG. 1 is a general perspective overview of the service equipment according to the present invention;

FIG. 2 is a cross-sectional view of spring loaded locating pins, within the service equipment according to the present invention;

FIG. 3 is an illustration of the electrical connectors in the service equipment according to the present invention;

FIG. 4A is a perspective view of the clamping apparatus within the service equipment according to the present invention;

FIG. 4B is a cross-sectional view along IV—IV of FIG. 4;

FIG. 4C is an enlarged perspective view of a key connector between base plates of the clamping apparatus and stationary service unit shown in FIG. 4A;

FIG. 5A is a perspective view of the clamp assembly according to the present invention;

FIG. 5B is a side view of the Geneva cam driver of the clamp assembly;

FIG. 5C is a side view in cross section of the Geneva cam driver of FIG. 5A;

FIG. 5D is a side view of the irregular Geneva cam of the clamp assembly; and

FIG. 5E is a side view of the Geneva cam driver and irregular Geneva cam of the clamp assembly illustrating the operation of the clamp assembly.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 is a general overview of the service equipment **10**. The service equipment **10** comprises a detachable service unit **20** and a stationary unit **50**. Detachable service unit **20** includes a housing **28** having an exterior plate **22** which abuts and mates with an exterior plate **52** of stationary unit **50**. A clamping apparatus **60** located within stationary unit **50** clamps detachable service unit **20** onto stationary unit **50**. Further, a pair of base clamp assemblies **120** and **122** are also located within stationary unit **50** to clamp clamping apparatus **60** onto a base plate **54** of stationary unit **50**.

A plurality of scallops are formed on each of the abutting faces of exterior plate **22** of detachable service unit **20** and exterior plate **52** of stationary unit **50** to facilitate accurate positioning and lateral alignment of the detachable service unit onto the stationary unit. The scalloped faces also facilitate efficient dissipation of unwanted heat generated within service equipment **10**. The scallops are formed at about a 45° angle, which increases the thermal interface contact area between exterior plates **22** and **52**. Further, a plurality of circulation pipes **58** are formed within the scallops of exterior plate **52** for circulating a thermal coolant medium to dissipate the unwanted heat generated by various mechanical and electrical components within service equipment **10**. Circulation pipes **58** are connected to input and output pipes of a thermal-control system (not shown). The thermal coolant medium may be air, a non-freezing ammonia compound or other known substances.

Referring to FIG. **1**, detachable service unit **20** includes a power control interface **16** located on an exterior surface of detachable service unit housing **28**. Interface **16** includes electrical leads **18** which provide electrical connection to electrical connector **40** as shown. A connector **47** of a control device **48** can be coupled to power control interface **16** to send and receive signals to and from the electrical and mechanical devices within service equipment **10**.

As shown in FIG. **3**, electrical connector **40** of detachable service unit **20** mates with an electrical connector **46** of stationary unit **50**. A male plug **40***a* of electrical connector **40** is mounted in exterior plate **22** of detachable service unit **20**, and a female plug **46***a* of electrical connector **46** is mounted in exterior plate **52** of stationary unit **50**. Male plug **40***a* has a plurality of spring loaded and convex faced electrical pins **42**, and female plug **46***a* has a corresponding plurality of concave receptor pins **44** which mate with and are electrically coupled to corresponding ones of electrical pins **42**.

Electrical connectors **40** and **46** are designed to transmit signals for control and actuation of motors, as discussed below, to transmit electrical signals indicating the torque across the mating surfaces of exterior plates **22** and **52** to achieve proper pressure (psi) between the plates for proper thermal interface, and to transmit electrical signals indicating electrical continuity of other electrical connectors **56** and **57** when detachable service unit **20** is clamped onto stationary unit **50**. Further, unlike conventional electrical connectors, electrical pins **42** in the male plug need not physically enter the female plug to obtain proper electrical contact. Rather, spring loaded and convex faced electrical pins **42** need only contact the required contact area (i.e., the concave surface) of female receptor pins **44**. Due to the design, the spring loaded and convex faced electrical pins **42** also act as locating pins when detachable service unit **20** is clamped onto stationary unit **50**.

Additional electrical connectors **56** and **57** disposed in detachable unit **20** and stationary unit **50**, respectively, are designed to mate when the units are aligned.

As shown in FIG. **1**, exterior plate **22** is coupled to exterior plate **52** by means of four spring loaded locating pins **30***a*–**30***d* disposed on the corners of exterior plate **22**. As illustrated in greater detail in FIG. **2**, each spring loaded pin (one shown) comprises a pin **32** housed in a tubular pin housing **36** and biased by a helical spring **34**. Housing **36** includes interior stopping shoulders **37** which retain the head of the pin and prevent the pin from falling out of housing **36**. Screws **38** mount housing **36** to exterior plate **22** of detachable service unit **20**. Exterior plate **52** of stationary unit **50** has location points **51** formed as receiving holes in each corner to receive locating pins **32**. The spring loaded locating pins **30***a*–**30***d* aid in proper positioning of the detachable service unit **20** onto the stationary unit **50** prior to clamping, and ensure that the units do not shift with respect to each other during and after clamping. Pins **30***a*–**30***d* also aid in alignment of electrical connectors **40**, **46**, **56** and **57**.

FIG. **4A** shows clamping apparatus **60** in detail for manual or robotic installation or replacement of detach-

able service unit 20 from stationary unit 50. The clamping apparatus 60 has three major components: 1) a pair of opposing clamp units 62 and 64; 2) a drive shaft 66 secured to clamp units 62 and 64; and 3) a drive mechanism 68 for rotating drive shaft 66 to cause linear displacement of clamp units 62 and 64. Clamp units 62 and 64 are designed to slide linearly in opposite directions to engage clamping receptacles 24 and 25 formed in exterior plate 22 of detachable unit 20. Clamping apparatus 60 is mounted to a clamping base plate 70 which is detachable from base plate 54.

As shown in FIG. 4A, opposing clamp units 62 and 64 are identical. FIG. 4B illustrates clamp unit 62 in detail, which comprises a generally rectangular clamping plate 72, a rectangular clamp support 74 and a pair of identical linear ball guides 76 and 78 (only guide 78 being shown in FIG. 4B) coupled to clamping base plate 70. Clamping plate 72 has an acute clamping protrusion 80 with an outwardly extending beveled face designed to engage the beveled inner face of clamping receptacle 24 located in exterior face 22 of detachable service unit 20. Clamping plate 72 extends outwardly from a slot in exterior plate 52 of stationary unit 50. Clamp support 74 is attached to clamping plate 72 by a pair of identical dowels 82 and 84 (dowel 84 being shown in FIG. 4B) in a spaced relationship. Linear ball guides 76 and 78 are elongate rails secured to base plate 70 in a parallel relationship and are preferably made of a material having a low coefficient of friction. As seen in FIG. 4B, clamp support 74 has a runner 86 secured thereto for sliding engagement with linear ball guide 78. An identical runner is disposed on the other end of clamp support 74 for engagement with linear ball guide 76. Each ball guide may include grooves 88 for engagement with edges of its respective runner, as shown for example in FIG. 4B.

Drive shaft 66 is coupled between clamp units 62 and 64 and is a ball screw shaft having right hand threads on one end and left hand threads on the other end. As shown in FIG. 4B, a ball nut 90 is threadedly engaged on ball screw shaft 66 and is secured to clamp support 74. A ball nut 91 is also secured in the same manner on the other end of ball screw shaft 66 to clamp support 75 of clamp unit 64. Ball screw shaft 66 freely extends through grooves 92 and 94 in clamping plates 72 and 73 and is rotatably supported at each end by bearing supports 96 and 98 and at the center thereof by bearing support 100. Each end of ball screw shaft 66 has an end formation, preferably a ½-inch socket 102, for receiving a tool, such as a torque wrench. During rotation of drive shaft 66, the different pitch threads allow ball nuts 90 and 91 to travel down the shaft in opposite directions, thus expanding or contracting clamp units 62 and 64 with respect to each other.

Drive mechanism 68 comprises a pair of motors 104 and 106, preferably DC motors, coupled to drive shaft 66 via shafts 108 and 110 and miter gears 112, 113, and 114, 115 respectively. When electrical signals are sent to motors 104 and 106 from control device 48, each motor rotates its respective shaft and miter gear. Miter gears 112 and 114 transmit the rotation of shafts 108 and 110 to ball screw shaft 66. The rotation of ball screw shaft 66 causes ball nuts 90 and 91 to linearly move in opposite directions along the axis of the ball screw shaft 66. Because ball nuts 90 and 91 are rigidly coupled to clamp supports 74 and 75, and clamp supports 74 and 75 are slidably engaged with the linear ball guides, opposing clamp units 62 and 64 are moved linearly. As discussed above, the opposite threads on ball screw shaft 66 allow clamp units 62 and 64 to expand or contract with respect to each other while drive shaft 66 is rotated in a single direction. Using two motors 104 and 106 provides sufficient power to retain clamp units 62 and 64 securely within clamping receptacles 24 and 25 and also provides a backup system if one of the motors becomes inoperational due to mechanical or electrical failure.

Further, if both motors become inoperative, a person or robotic end effector can attach a tool, such as a torque wrench, to one or both of the ½-inch sockets 102 in the ends of drive shaft 66, and detachable service unit 20 can be manually unclamped and clamped to stationary unit 50 by rotating the torque wrench in the required direction.

In operation, a robotic arm or a person, such as an astronaut, positions detachable service unit 20 onto stationary unit 50. Exterior plates 22 and 52 are color coded to indicate proper positioning of detachable service unit 20 onto stationary unit 50. Detachable service unit 20 is moved in a longitudinal direction of the scallops until spring loaded locating pins 30*a*-30*d* engage their respective locating holes in stationary unit 50 and electrical pins 42 of electrical connector 40 are in contact with receptor pins 44 of electrical connector 46, indicating that detachable unit 20 is in the clamping position. An operator then engages connector 47 of control device 48 to control interface 16 in detachable unit 20 via a robotic end effector or astronaut's power pac. A signal, such as an LED on the power pac, will indicate to the operator that detachable unit 20 is not clamped, that electrical connectors 40 and 46 are in contact and that power can be supplied to drive mechanism 68.

Control device 48 then supplies power to drive motors 104 and 106 to rotate shafts 108 and 110 and miter gears 112 and 114 to cause rotation of drive shaft 66 in a first direction. In the preferred embodiment, 12 volts of electrical power are supplied to drive mechanism 68. As discussed above, rotation of drive shaft 66 causes ball nuts 90 and 91 to travel down shaft 66 and linearly displace clamp supports 74 and 75 on the linear ball guides causing the beveled faces of clamping plates 72 and 73 to engage clamping receptacles 24 and 25. The beveled faces aid in forcing exterior plates 22 and 52 toward each other in tight engagement.

Control device 48 has a current sensing linear integrated circuit for sensing the current supplied to the motors. The current is proportional to the torque applied across the mating surfaces of exterior plates 22 and 52. When the torque reaches a preset value, the power to motors 104 and 106 is removed. The preset value is representative of the required pressure per square inch across the scalloped faces of exterior plates 22 and 52 to achieve the desired thermal interface. Additionally, data signals, such as an LED, will provide an indication to control device 48 that detachable service unit 20 is properly clamped to stationary unit 50.

The above sequence also applies to unclamping detachable service unit 20 from stationary unit 50, except that motors 104 and 106 turn drive shaft 66 in a second opposite direction to the first direction to contract clamp units 62 and 64 and the sequence is reversed.

FIG. 5A illustrates in detail one of the base clamp assemblies 120 which clamps base plate 70 of clamping apparatus 60 onto base plate 54 of stationary unit 50 for quick removal or attachment of clamping apparatus 60 in the event that clamping apparatus 60 needs repair or

replacement. A pair of identical base clamp assemblies **120** and **122**, shown in FIGS. **1** and **4A**, are located in stationary unit **50** on opposite sides of base plate **70** of clamping apparatus **60**. A plurality of dovetail grooves and key connectors may also be provided between the base plates as shown in detail in FIG. **4C**. Base plate **54** of stationary unit **50** and clamping base plate **70** have opposed dovetail grooves **124** and **126**, respectively, and a complementary dovetail key connector **128** is disposed within the grooves to couple base plate **54** to clamping base plate **70** (the spacing between the grooves and connector has been exaggerated for clarity). Key connectors **128** allow base plate **70** to slide with respect to base plate **54**. Clamping apparatus **60** can therefore be accurately aligned to slide in and out of stationary unit **50** along the longitudinal axis of key connectors **128**. Once clamping apparatus **60** is in place within stationary unit **50**, clamp assemblies **120** and **122** engage the edge of clamping base plate **70** at clamp supports **130** and **131**, shown in FIG. **5A** with respect to clamp assembly **120**.

Referring to FIG. **5A**, clamp assembly **120** comprises a pair of Geneva cam drivers **132** and **134**, a pair of irregular Geneva cams **136** and **138**, a drive shaft **140** coupled to Geneva cam drivers **132** and **134** and an optional drive mechanism **142** operably connected to the drive shaft **140** through miter gears **143** and **145**. Drive shaft **140** has end formations **144** and **146**, such as ½-inch sockets, located at each end for receiving a tool, such as a torque wrench (not shown), for rotating drive shaft **140** in first and second directions to clamp and unclamp base plate **70**. Drive mechanism **142** includes a gear assembly coupled to drive shaft **140** and may also be used to rotate drive shaft **140** to clamp and unclamp base plate **70**.

Drive shaft **140** is rotatably supported at each end and the center thereof by a series of uprights **148**, **150**, and **152**. Each irregular Geneva Cam **136** and **138** is supported by a rotatable shaft **154** and **156**, respectively, supported by a pair of uprights. For example, shaft **156** is rotatably supported by uprights **158** and **160**.

As shown in FIG. **5B**, Geneva cam driver **132** has a central spline **162**, an engagement aperture **164**, a disengagement aperture **166**, and an interlocking formation **68**. A roller **172**, as shown in FIG. **5C**, is bolted into disengagement aperture **166** to form a disengagement roller of Geneva cam driver **132**. A roller **170** is also bolted into engagement aperture **164** to form an engagement roller. Engagement and disengagement rollers **170** and **172** are located at substantially opposite ends of Geneva cam driver **132**, and spline **162** and interlocking formation **168** are located therebetween. Geneva cam driver **134** is identical to Geneva cam driver **132**. Shaft **140** is connected through the splines of Geneva cam drivers **132** and **134** for transmitting rotation of shaft **140** from the torque wrench or drive mechanism **142** to Geneva cam drivers **132** and **134**.

As shown in FIG. **5D**, irregular Geneva cam **136** has an engagement slot **174** located about 90° from a disengagement slot **176**, an arc groove **178** formed on its outer circumference located between engagement and disengagement slots **174** and **176**, and a clamp face **180** located approximately 90° from disengagement slot **176**. Further, irregular Geneva cam **136** has a central spline **182** about which it rotates. Irregular Geneva cam **138** is identical to cam **136**. Irregular Geneva cam **136** is carried by shaft **154** through spline **182**, and irregular Geneva cam **138** is carried by shaft **156** through a similar spline.

When clamping apparatus **60** is to be unclamped from stationary unit **50**, a person or robotic end effector attaches a torque wrench to at least one of the end formations **144** and **146** and rotates shaft **140**. Alternatively, drive mechanism **142** can be controlled by controller **48** to rotate shaft **140**. The rotation of shaft **140** causes rotation of Geneva cam drivers **132** and **134**. As shown in FIG. **5E** (solid lines), Geneva cam driver **132** rotates about shaft **140** to engage disengagement roller **172** in disengagement slot **176**. Such movement will cause irregular Geneva cam **136** to rotate about shaft **154** and lift clamp face **180** from clamp support **130** of clamping base plate **70**. Interlocking formation **168** slidingly mates with arc groove **178** during rotation.

When clamping apparatus **60** is properly positioned on base plate **54** of stationary unit **50**, opposite rotation of shaft **140** by the torque wrench or drive mechanism **142** causes Geneva cam driver **132** to engage engagement roller **170** in engagement slot **174**. As shown in FIG. **5E** (dotted lines), such movement will cause rotation of irregular Geneva cam **136** about shaft **154**, locking clamp face **180** onto the top surface of clamp support **130** of clamping base plate **70**.

Using the above clamping apparatus and base clamp assemblies, service equipment **10** can be easily and quickly serviced in hostile environments, and unwanted heat generated within service equipment **10** can be efficiently dissipated. The foregoing embodiments are intended to be illustrative and not limiting. Various modifications may be made without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A clamp assembly for removable securement of units in a modular assembly comprising:

at least one Geneva cam driver having a spline, an engagement roller and a disengagement roller;

at least one Geneva cam having an engagement formation for receiving said engagement roller of said at least one Geneva cam driver, a disengagement formation for receiving said disengagement roller of said at least one Geneva cam driver and a clamp face;

a drive shaft coupled to said spline of said at least one Geneva cam driver; and

an operating mechanism for rotating said drive shaft in a first direction to cause said engagement roller to engage said engagement formation and cause said clamp face to clamp a unit to the modular assembly, and for rotating said drive shaft in a second direction to cause said disengagement roller to engage said disengagement formation and cause said clamp face to unclamp the unit from the modular assembly.

2. The clamp assembly of claim **1** wherein said engagement and disengagement rollers are located substantially at opposite ends of said at least one Geneva cam driver and said spline is located therebetween.

3. The clamp assembly of claim **1** wherein said Geneva cam driver has an interlocking formation disposed on a planar face surface thereof and said Geneva cam has an arc groove on a side surface thereof, said interlocking formation slidingly engaging said arc groove during clamping and unclamping.

4. The clamp assembly of claim **1** wherein said engagement formation is disposed about 90 degrees from

said disengagement formation and said clamp face is disposed about 180 degrees from said engagement formation.

5. The clamp assembly of claim 3 wherein said arc groove is formed on an outer circumferential surface of said at least one Geneva cam and between said engagement and disengagement formations.

6. The clamp assembly of claim 1 wherein said at least one Geneva cam further comprises a pivotal spline, said pivotal spline being disposed along an axis of rotation of said at least one Geneva cam.

7. The clamp assembly of claim 1 wherein said operating mechanism comprises a motor and a gear coupling said motor to said drive shaft, said motor causing rotation of said drive shaft and gear in said first and second directions upon receiving first and second input signals.

8. The clamp assembly of claim 1 wherein said drive shaft has ends and at least one end has a formation for engagement with a torque wrench for rotating said drive shaft.

9. A clamping apparatus for manual or robotic replacement of a detachable service unit from a stationary unit in hostile environments comprising:

a base plate;

a pair of opposing clamp units coupled to said base plate;

a drive shaft operably mounted on said base plate and secured to said pair of opposing clamp units;

a drive mechanism mounted on said base plate for rotating said drive shaft to cause linear displacement of said pair of opposing clamp units and thus move said pair of opposing clamp units between a clamped position and an unclamped position to clamp and unclamp the detachable service unit to and from said base plate;

a plurality of Geneva cam drivers mounted on said stationary unit, each of said Geneva cam drivers having an engagement roller and a disengagement roller;

a plurality of Geneva cams mounted on said stationary unit adjacent to said Geneva cam drivers, each of said Geneva cams having an engagement formation for receiving the engagement roller of an adjacent Geneva cam driver, a disengagement formation for receiving the disengagement roller of said adjacent cam driver and a clamp face for contacting said base plate, and

operating means for rotating said Geneva cam drivers in a first direction to cause the engagement rollers to engage the engagement formations and cause the clamp faces to contact the base plate thereby attaching the same to the stationary unit and in a second direction to cause the disengagement rollers to engage the disengagement formation and cause the clamp faces to release the base plate.

10. The clamping apparatus of claim 9 wherein each of said clamp units comprises a clamping plate for engagement with the detachable service unit, a clamp support coupled to said clamping plate and at least one linear ball guide, said clamp support slidingly engaging said at least one linear ball guide and being linearly moveable along said at least one linear ball guide.

11. The clamping apparatus of claim 9 wherein said drive shaft comprises a threaded shaft and a nut threadedly engaging said threaded shaft and rigidly coupled to one of said pair of opposing clamp units to cause linear displacement of at least one of said pair of opposing clamp units.

12. The clamping apparatus of claim 11 wherein said drive shaft has first and second ends, said first end having right hand threads and said second end having left hand threads.

13. The clamping apparatus of claim 9 further comprising at least two bearing supports, said bearing supports supporting said drive shaft at opposite ends of said drive shaft and being coupled to said base plate.

14. The clamping apparatus of claim 9 wherein said at least one drive mechanism comprises a motor, a rotatable gear being engaged with said drive shaft and a shaft connected to the motor, and a gear coupled to said shaft, said motor causing rotation of said gear and said shaft in a direction upon receiving an input signal from an exterior source.

15. The clamping apparatus of claim 9 wherein said drive mechanism comprises a torque wrench controllable by a robotic end effector or user coupled to one end of said drive shaft, wherein rotation of said torque wrench causes said drive shaft to rotate.

16. The clamping apparatus of claim 9 wherein said drive has two ends, and at least one of said ends includes an end formation for receiving a tool to rotate said rotational coupler.

* * * * *